

Chidester, F. E. - Fish enemies of the salt-marsh mosquitoes.

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A BIOLOGICAL STUDY OF THE MORE IMPORTANT OF THE FISH
ENEMIES OF THE SALT-MARSH MOSQUITOES

NEW JERSEY
AGRICULTURAL
Experiment Stations
BULLETIN 300

NEW BRUNSWICK, N. J.

A

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MAY 1 1917

NEW JERSEY

AGRICULTURAL EXPERIMENT STATIONS

BULLETIN 300

JUNE 1, 1916

A BIOLOGICAL STUDY OF THE MORE IMPORTANT OF THE FISH ENEMIES OF THE SALT-MARSH MOSQUITOES ¹

by

F. E. Chidester, Ph. D.

INTRODUCTION

The mosquito has a long list of natural enemies and if the exact standing of each were well understood it is possible that some of the more important might be artificially encouraged to a point where their warfare on the mosquito would prove the most efficient factor in its satisfactory control. With this in mind the writer was invited to examine the possibilities of certain fishes already known as mosquito destroyers. The study was begun September 19, 1914 and continued for a little over one year.

The study consisted of making collections of fishes throughout the year with records of tides, salinity, specific gravity and temperature of the waters in which they were taken; a study of the stomachs of samples from the collections; experiments on the resistance of the fishes to high concentrations of salts; experiments on the effect of highly concentrated sea water on the development of the embryos; and many feeding experiments, using mosquito larvæ, *Dytiscus*, daphnids and other known food of the killifishes. These experiments were supplements by other experiments on the importance of the water tiger (*Dytiscus*) and the tadpoles of several species of frogs as mosquito larvæ exterminators. The last named group of experiments will be elsewhere discussed.

ENEMIES OF THE MOSQUITO

In outlining the problem, it was found desirable to prepare a list of the animals recognized as foes of the mosquitoes, and with

¹ Contributions from the entomological laboratory; Thomas J. Headlee, Ph. D., Entomologist.

the idea that it may be used in later studies of this sort, it is presented with this paper. The list is compiled from many sources, but chiefly from the papers of Smith (13), Howard, Dyar and Knab (3) and Headlee (2).

Invertebrates

Protozoa—*Spirochaeta culicis*, *Diplocystis*, *Nosema stegomyiae*, *Crithidia fasciculata*, *Herpetomonous algeriense*, *Trypanosoma culicis*.

Coelenterata—*Hydra fusca*, *Hydra viridis*.

Platyhelminths—*Agamodistomum martiranoi*.

Nemathelminths—*Agamomermis culicis*.

Arthropoda—*Hydrophilus obtusatus*, *Dytiscus marginalis*, *Acilius sulcatus*, *Nepa*, *Notonecta*, *Ranatra fusca*, *Aeschna*, *Erythemis simplicicollis*, *Psorophora ciliata*, *Megarhinus septentrionalis*, *Lutzia bigotii*, *Lesticocampa*, *Corethra*, *Tanypus dyari*, *Lispa sinensis*, *Horpopeza obliterate*, *Tahydromia macula*, *Cordilura haemorrhoidalis*, *Monedula signata*, *Emesa longipes*, *Salticus*, *Crangon vulgaris*.

Vertebrates

Pisces—*Fundulus heteroclitus*, *F. majalis*, *F. diaphanus*, *Gambusia affinis*, *Cyprinodon variegatus*, *C. calaritanus*, *Heterandria Abramis chrysolenca*, *Carassius auratus*, *Eupomotois gibbosus*, *Mollinesia latipennis*, *Girardinus poeciloides*, *G. caudimaculatus*, *Haptochilus*, *Lucius am.*

Amphibia—*Rana pipiens*, *Rana palustris*, *Discoglossus pictus*, *Triton cristatus*, *T. alpestris*, *Diemyctylus tortosus*, *Amblystoma opacum*.

Reptilia—*Ptychozoon homalecephalum*.

Aves—*Chordeiles virginianus*, *Choetura pelagica*, *Petrochelidon lunifrons*, *Iridoprocne bicolor*, *Hirundo erythrogastra*, *Progne subis*, *Riparis riparia*, *Tachycineta thalassina lepida*, *Myiochanes virens*, *Sayornis phoebe*, *Tyrannus tyrannus*, *Anas platyrhynchos*, *Aegialitis semipalmata*, *Pisobia pusillus*.

Mammalia—*Eptesicus fuscus*, *Homo sapiens*.

FISHES KNOWN TO EAT SALT-MARSH MOSQUITOS

No writer on the subject of the relation of fishes to the mosquito problem can pass lightly over the magnificent work done by Mr. William P. Seal (10) of Delair, New Jersey, who for years has been known as an authority on the subject. Independently and later as fish expert to Dr. J. B. Smith, Mr. Seal showed the importance of utilizing the fish as one of the most important groups preying on the mosquitoes. In Dr. Smith's report (13) and in later papers Mr. Seal (10, 11) has pointed out clearly that on the salt marshes, *Fundulus heteroclitus*, *Fundulus diaphanus*, *Cyprinodon variegatus*

and *Gambusia affinis* are all extremely important enemies of the mosquito larvæ.

As the writer was concerned primarily with the salt-marsh mosquito, his problem was to discover what species of fish was most effective on the marshes, both ditched and unditched. While the work herewith recorded is largely from Middlesex and Monmouth Counties, the excellent report system of the Entomologist and the willing cooperation of the many chief inspectors and inspectors extend the records throughout the entire State.

In the following pages we shall show that not only is *Fundulus heteroclitus* the most voracious enemy of the larvæ, pupæ and adults of the mosquito, but that on account of the migration habits, numbers and supremacy of the species, it is the most important natural factor in the extermination of the salt-marsh mosquito. It is worthy of note that *Fundulus heteroclitus* is also an important enemy of the green-headed fly.

POOLS AND STREAMS UNDER OBSERVATION

In order to study the fish closely and extend the period of observation under natural salt-marsh conditions, a marsh near Bonhamtown, New Jersey, and about three miles from the City of New Brunswick, was selected as the chief station for study. Here collections were made at intervals from September 19, 1914 to August 15, 1915.

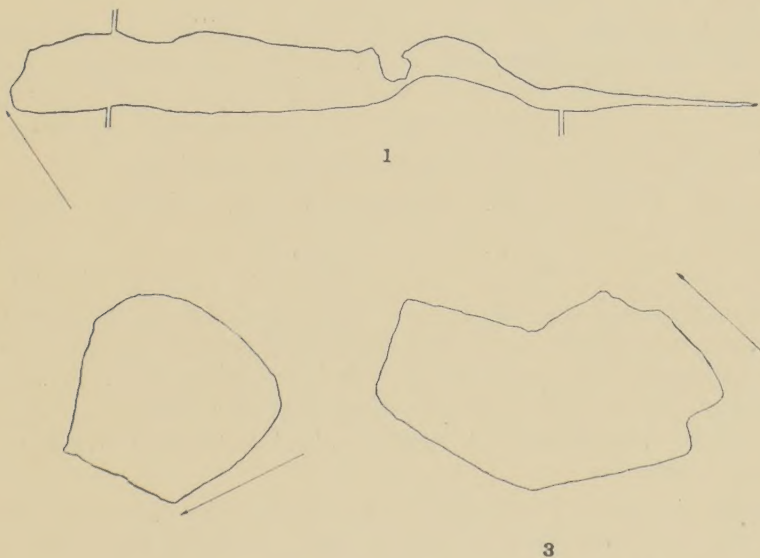


Fig. 1.—Diagram of salt-marsh area showing pools from which fish were taken. Scale: 1 inch = 12 feet.

During three weeks of June, 1915, many experiments and observations were made at the Marine Biological Station, Woods Hole, Massachusetts. Some of the problems attacked were the effect of high concentration of salts on the viability of *Fundulus*; the effect of highly concentrated sea water on the development of the embryo of *Fundulus heteroclitus*; the water tiger as food for *Fundulus heteroclitus*; adaptation of *Fundulus diaphanus* to salt water; acclimation of the tadpole to salt water; habits of the migrating *Fundulus*; and effect of varying the flow of water on the activity of *Fundulus heteroclitus*. The problems named will be further discussed in later papers, but the most important facts germane to the present discussion will be incorporated in the pages following in appropriate places.

It is a pleasure to acknowledge the kindness of Dr. F. R. Lillie, Dr. Gilman A. Drew and Mr. George Gray of the Marine Biological Laboratory in placing at my disposal the laboratories and supplies of their institution. The excellent library was of great help, also.

At the suggestion of Dr. T. J. Headlee, a trip was made to Atlantic County early in July to investigate the conditions in virgin territory undrained by human agents. Marsh land near Beach Haven, Tuckerton, and Atlantic City was studied and the dispersal of fishes noted. The Tuckerton Creek and many creeks near it also were studied.

At the Bonhamtown meadows work was intensified on three permanent pools, additional studies being made of conditions in many other small and large pools and on the activity of the fishes in the ditches and along the shores.

These pools were surveyed by Mr. R. B. Hiller, an engineering student of Rutgers College, and were sounded at intervals. Collections were made from the pools and from ditches and larger pools by means of a 20-foot minnow seine and several small dip-nets.

Table of collections with species of fish identified
Number of *Fundulus* het. *Cyprinodon* var. *Apeltes* *Anguilla*.
collections

29	1581	105	19	22
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Although *Fundulus majalis* did not appear on the Bonhamtown marshes, the species is fairly well distributed along the New Jersey coast, running in and out with the tides, confining itself to the salt and brackish water and not migrating into the shallows. Because of this habit, it cannot enter largely into the extermination of the salt-marsh mosquito.

Besides the fish named, *Lucania* and *Menidia* were collected at times when the tides were especially high. Among the *Arthropoda* collected from the pools under observation were *Dytiscus* and its larvæ the water tiger, *Crangon vulgaris* and *Palaeomonetes* (shrimps) and *Notonecta*. Many small unidentified myriapods were dug up

with the fish when collections were made in midwinter from the mud in the bottoms of the pools.

MIGRATION IN FISHES

Like its relative, *Fundulus majalis*, *Fundulus heteroclitus* is most normal in activity in moving water. *Fundulus majalis*, which moves in and out with the tides, has been studied by Dr. S. O. Mast, who finds that it is not only prone to move with the tides, but that when the outlet to the ocean is plugged, the fish will convey themselves overland by flopping in the general direction of the ocean. Mast (5) shows that the fish actually keep their sense of direction in the overland course. He concludes that the fish "apparently remember" the location of the outlet. As Mast can find no external features which seem capable of guiding, he concludes that the behavior is dependent on internal factors.

Fundulus heteroclitus migrates to the shallowest pools of the salt marshes and travels up streams past the salt water to water of a very low salinity. When it is land-locked it stays throughout the winter in the mud in the bottom of salt marsh pools. It is significant that *Fundulus heteroclitus* will return to the ocean on the tides in the late fall, and that it ceases coming to the marshes when the water reaches a temperature of about 45°F.

Records made with the salinometer and thermometer from November, 1914, to August, 1915, show that *Fundulus heteroclitus* react negatively to water of a low salinity when the temperature is below 45°F. As the temperature rises and the marsh pools and streams are increased in salinity by the incoming high tides of spring, the fish migrate freely and stay in water which is fresher than they will tolerate at colder temperatures.

Permanent unditched pools contained killifishes (*F. heteroclitus* and *F. diaphanus*), eels, sheeps-head minnows (*Cyprinodon*) and shrimps, throughout the entire winter. Field records of the three permanent and four temporary pools observed, showed that during November, the fishes attempted to burrow in the bottoms as the temperature stood between 43°F. and 47°F. In the case of the permanent pools whose bottoms are covered with soft mud and finely torn eel grass and sedge, the fish burrowed down to a depth of 6 or 8 inches and many remained there in the black oozy mud at a temperature ranging from 40°F. to as high as 45°F. On sunny days some of the fishes came out and swam around, plainly visible under the ice which was sometimes one-fourth to one-half inch thick over the salt pools.

In the temporary pools where the bottoms are composed of matted and hardened grass bound together with clay, the fish rapidly succumb at the onset of cold weather. Specimens with whitened fin-edges secured early enough in the morning to be certain that the sun's rays had not materially changed the temperature of their pools were

found to be feebly endeavoring to burrow into the mud. The water in the pools from which these dying fish were taken registered 43°F. and 44°F. Some of the dying fish revived when brought to the laboratory and were kept for several weeks before being preserved.

While temperature apparently explains the migration inland and the subsequent return to the salt water, it is interesting to note that during a period of two or three weeks in August, during the past summer, the fish did not migrate to the shallows. This condition may not be in evidence every year, but some data indicate that it is the usual thing. Records taken by Mr. F. E. Mehrhof at Bonhamton in late July and early August showed that the killifish were very scarce at that time. Mr. Russel Gies, chief inspector of the Union County Mosquito Extermination Commission reported that during the period between August 4 and August 10, the fish did not run into the ditches and could not be attracted into them by meat baits. While the meat bait probably caused acids of decay which would drive the fishes away, the fact that there was no migration for at least a week seems important. Records from other inspectors throughout the State showed that there is apparently a period of about two weeks in August marked by almost complete absence of the actively feeding killifishes from the marshes.

Among the explanations which occur to me the following important ones will be further discussed elsewhere. First, the temperature of the water may be sufficiently high to reverse the reaction of the fish to fresh water and cause it to return to salt; second, the exhaustion subsequent to spawning may cause the fish to hesitate about wandering with the tides; third, appetite may be satisfied in the case of a large body of fish which have been living in brackish water and which begin to return to the salt, to be replaced by others which have not been far inland. These points will be taken up in detail on page 10.

Some of the finest experimental work on fishes has been done by Dr. Victor E. Shelford (12) of the University of Illinois and his students, Dr. W. C. Allee and Dr. M. M. Wells. Much of the discussion on migration to follow is based on their findings.

Shelford and Powers have shown (12) that herring are sensitive to temperature differences as small as 0.2°C.

Johnstone (4) has shown that the migration of herring in Europe is closely associated with the salinity and temperature of the sea.

Shelford and Powers (12) have shown that alkalinity and acidity are more important than salinity. The herring and salmon experimented with reacted to small fractions of a cubic centimeter per liter of H_2S and became negative to sea water which was slightly more acid than the fresh.

Wells (16, 17, 18, 19) takes issue with Marsh who claims that "water which will support life must be slightly alkaline." Wells claims (18, 19) that the water which seemed slightly alkaline when

methyl orange was used as an indicator, was probably acid to phenolphthalein.

Wells shows that fresh-water fishes recognize and react to the presence of salts in solution, the reaction being such as will bring them into their optimum salt concentration. From his own and from Shelford's work on the salt-water fishes, Wells concludes that fresh water and probably salt water fishes are not so sensitive to salt ions as they are to hydrogen and hydroxyl ions. He also shows that starvation causes some fishes to select higher concentrations of salts than those normally selected, while the reverse is true of other species of fish.

Roule (9) believes that salmon migrate to a richer supply of oxygen.

LIFE HISTORY OF *FUNDULUS HETEROCLITUS*

Fundulus heteroclitus is "the killifish of Schopff, the yellow-bellied and the white bellied killifish of Mitchell and the big killifish and barred killifish of De Kay. The Indian name 'mummichog' is applied to this as well as other species and some persons call it the salt water minnow. It is also called the mud-fish, cobbler and pike minnow." [Bean (1)].

The killifishes are characterized by banded markings, rounded fins, a very convex tail fin, short head, obtuse snout, space between the eyes very flat, lower jaw projecting, and a length of not more than 6 or 7 inches.

The male reaches a length of about 5 inches and is easily distinguished at all ages and in all seasons by the presence of a number of transversely arranged silver bars on the sides and a yellow or orange colored belly. The ground work of the body is dark green, and in mature specimens at the breeding season there are numerous white and pale yellow spots of color on the sides. The dorsal fin of the male bears a dark spot at the base of the last rays; in the young male this dark spot is subdivided into two blotches. The *vas deferens* extends to the anal fin or even a little way along the anterior ray.

The young female has dark bands like the silver bands of the male, and during the spawning season some older females show the dark bands against their olive ground color. The majority of the older females, however, rarely show the transverse bands. The oviduct extends along the anterior ray of the anal fin about two-thirds its distance.

It is interesting to note that the killifishes have the power of changing their color rapidly to agree with their background. This serves them well in escaping the notice of some of their enemies, as well as enabling them more readily to approach their living food.

In New Jersey in the vicinity of New Brunswick, the spring migration begins as early as the latter part of March and gravid females were found as early as April 19, 1915. The spawning season

for older fish reaches its height during the latter part of May in this latitude. After spawning, the fish do not seem active for a time and as previously indicated, we find that migration far inland ceases almost entirely in New Jersey during about two weeks in August.

When we consider that there are at least three kinds of fish of the same species coming in with the tides toward the fresher waters, it is easy to explain on theoretical grounds, at least, such a condition as has been mentioned.

In the very early spring we have the larger males and females which will spawn in a week or two; a large number of medium-sized fish which come in to feed but which will not spawn for a month at least; and lastly, the yearlings, which will not spawn until late in August or, if of the late brood of the previous year, probably not until the next summer. Knowing that after each fish is completely spent of its genital products there must be a period of comparative sluggishness, we find that the absence of the larger fishes from the marshes in August is readily explained; this also explains the relatively few medium-sized fish on the marshes in August. The fact that even the smaller fish do not appear in any great numbers in the middle of August, leads one to believe that another factor enters into the matter.

This factor, the writer believes, is that of warmth. The fish which reacted positively to the fresher water as the temperature increased inland in the spring, may have reacted to the lower salinities on the marshes more readily when in a state of starvation. In the middle of August there are three conditions which might influence the return: first, the higher temperature which might reverse the reaction to fresher water; second, the condition of sluggishness following spawning and inhibiting any battle with tides; and last, the fact that the animals are well fed and hence in a condition to return to their abode for the winter.

Early in September large numbers of *Fundulus heteroclitus* return to the marshes with the tides, and they continue to run in and out, staying for shorter and shorter periods as the cold increases in the fresher streams, until finally they cease running until the following spring.

The mating habits of *Fundulus heteroclitus* have been very well described by H. H. Newman (6) in the Biological Bulletin for 1907.

The presence of males and females in aquaria together is known to be sufficient to cause the females to spawn. If a male is not present, when a gravid female is too much distended with eggs she will assume a peculiar S shape, and vibrating her tail, will extrude some of her eggs. If a male is present, he will usually seek out and corner a female about ready to spawn and lock his dorsal and anal fins against hers. Then follows the simultaneous extrusion of eggs and sperm.



1



2

Plate I. Fig. 1.—*Fundulus heteroclitus* male.

Fig. 2.—*Fundulus heteroclitus* female.

In nature, although many of the eggs are eaten by other fish and even by the mother, the majority of them sink to the bottom in mud and are there protected. The development of the eggs of *Fundulus* depends on the temperature of the water, but is about three weeks in length.

During development, the hardy eggs of *Fundulus heteroclitus* may be subjected to almost unbelievable maltreatments and still develop. They will develop in water ranging from distilled to even as high as 40 per cent ¹ salt. Placed in solutions of alcohol, ether, chloretone and magnesium chloride in sea water, many develop abnormally, but develop to hatching. [Stockard (14, 15)].

The young fish hatches with a yolk sac which rapidly disappears, leaving it to feed on minute plankton. By the following spring after hatching a young *Fundulus* is ready to eat much the same foods as the largest of its kind.

The worst enemy of the killifish is probably his own kind. Many eggs are eaten by the adults of the same species. Among the fish known to eat *Fundulus heteroclitus* are the striped bass, weakfish, smelt, blue fish and dogfish. Sea birds and even domestic ducks are also known to be enemies of the little killifish. [Bean (1)].

Man takes advantage of the fact that killifishes are easily obtainable and uses quantities of them as bait for other larger fish.

FOOD OF THE KILLIFISHES

The very young *Fundulus* of a little less than a year can eat as many as six pupæ of the mosquito in half an hour and survive the meal. In an experiment performed purely as an extra, I placed a very small *Fundulus* (1cm.) in a jar with six pupæ of *Aedes sollicitans* Wlk. which were at least half its length. In 30 minutes all the pupæ were eaten. The first one seized was eaten in about 6 minutes.

Examinations of the stomachs of adult *Funduli* showed that they eat larvæ, pupæ, and adults of all the salt-marsh mosquitoes. They also eat *Dytiscus*, *Notonecta* and many Daphnids. In the winter small quantities of algal matter and a few small shrimps constitute the most of the food of the active individuals. In the early fall, the chief food besides mosquitoes seems to be insect and snail eggs and occasionally a few fish eggs.

Mr. T. C. Nelson of the University of Wisconsin, informs me

¹From unpublished experiments by the author.

that he has seen *Fundulus heteroclitus* jump out of the water to catch mosquitoes, green-head flies and Ephydra.

EFFICIENCY OF *FUNDULUS HETEROCLITUS* AS A MOSQUITO EXTERMINATOR

In the laboratory many experiments were performed with *Funduli* of all ages to determine how many mosquito larvæ they will take at one meal. Out of about 30 experiments, the average number was 25. After eating from 20 to 30 larvæ, a *Fundulus* apparently needs time to digest, as it rarely begins eating again for at least two hours.

The best record of feeding for a medium-sized *Fundulus* was 15 mosquito larvæ of the second moult in 5 minutes.

In order to determine the capacity of killifishes under laboratory conditions, when fed 10 larvæ at a time during a period of about 8 hours of the day, experiments were performed as follows.

Two large killifishes (about 7 cm, or 2.75 inches) two medium-sized killifishes, (about 5 cm, or 2 inches) and two small killifishes (about 3 cm, or 1.20 inches) were selected as suitable for the experiments. All were apparently in perfect health and among the most vigorous of the lot collected at this time. Six aquarium jars, each 12 inches in diameter and 4 inches in height were prepared with salt water previously boiled and diluted to 6 per cent salt. Into each of the jars a fish was placed and allowed to accustom itself to its surroundings for a period of about 12 hours. A mixture of mosquito larvæ of the species *Aedes sollicitans* Wlk., *Aedes cantator* Coq. and *Culex salinarius* was carefully sorted into larvæ of approximately the same age and size, and held in readiness for the feeding experiment.

Beginning on the fourth of August, 1915, Mr. F. E. Mehrhof began feeding the larvæ to the fish, continuing his experiment for a period of four days. The plan of the experiment was to observe the fish at intervals of 30 minutes and supply them with larvæ of the second moult in groups of 10. When more than one larva was left in the jar the fish was not given a new lot of 10. The presence of larvæ which had passed through the body of the fish as excrement was ignored.

The graphs which follow show the average consumption of each fish for the period of four days.

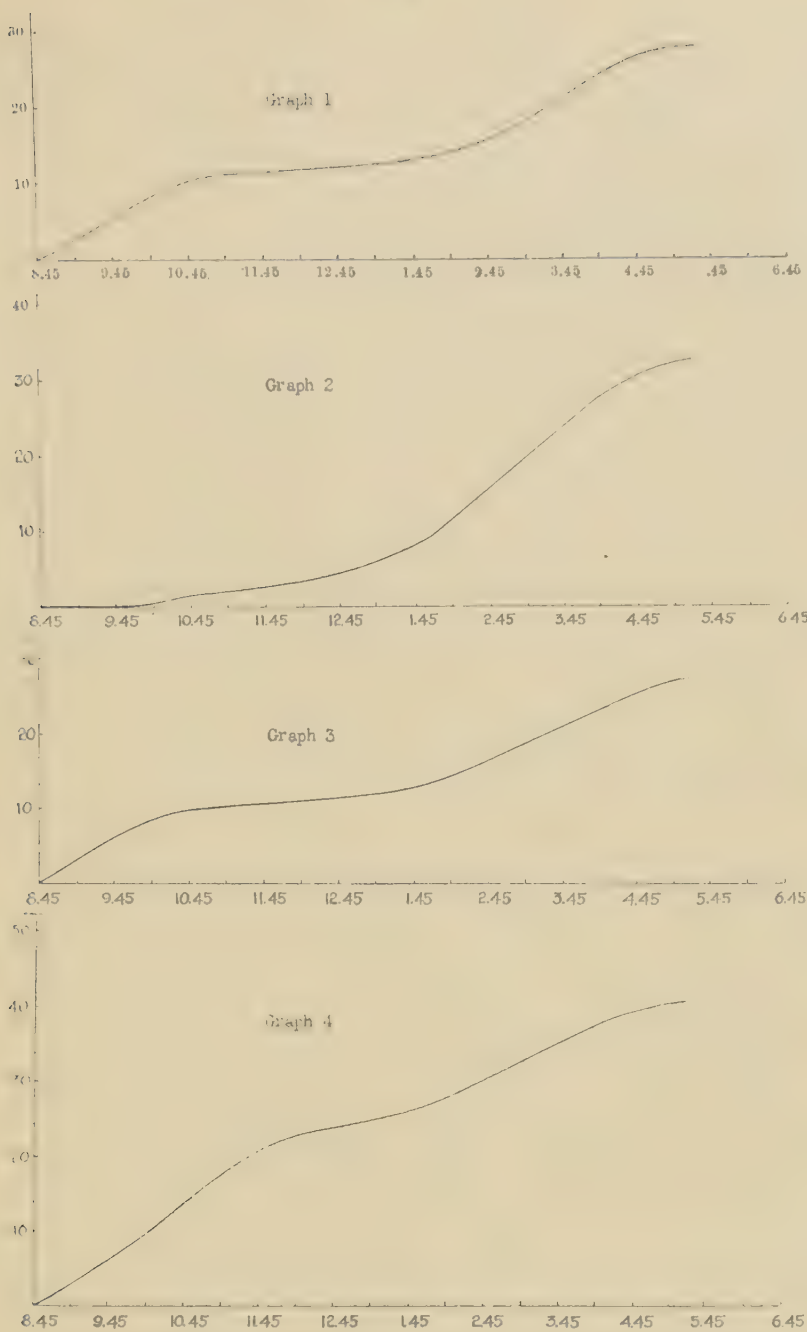


Fig. 2—Diagram showing feed curves for four days:

Graph 1—Fish No. 1.

Graph 2—Fish No. 2.

Graph 3—Fish No. 3.

Graph 4—Fish No. 4.

In discussing the results obtained we must first point out some of the most apparent errors in the experiment. The experiment was performed during the hours 8 a. m. to 5 p. m. and therefore the night life of the fish is not recorded. It is probable that many more larvæ would have been eaten had they been given to the fish very early in the morning. Others would have been eaten as late as 7:00 p. m. and probably some would have been eaten in the darkness of the night. Again since the killifish depends almost entirely on its visual sense in locating the mosquito larvæ and since the specimens used could get no new lot of 10 larvæ until all but one larva, dead or alive, was eaten, many minutes of idleness and probably hunger were passed over. Lastly, the food was entirely of mosquito larvæ.

Briefly summarizing the results of the experiments we may say: that first, the highest record of daylight consumption for the period of four days was 123 larvæ; other fish ate more but did not survive; second, the highest record of daylight consumption of larvæ for three of the four days was 135, and then the fish *died*; third, the total number of larvæ consumed during four days and three nights by four of the fish which survived was 600: the total number consumed by these same fish for the daylight hours only was 451; fourth, the greatest number of larvæ eaten in one day was 70, but two of the fish made this record and one of them ate but 20 larvæ the following day and then died; fifth, the two largest fish were the only ones which survived the whole period of four days and seemed ready for more food at the end of the experiment. The average consumption of the two survivors per day for the period of four days was 35 larvæ per day each. The average daylight consumption for that time was 27.25 larvæ each.

It is obvious that experiments performed on such a small number of fish for such a short period of time prove little. They do show, however, that the capacity of medium-sized killifishes of the species *Fundulus heteroclitus* is enough to make it a formidable enemy of the mosquito larvæ.

It is interesting to note that *Fundulus heteroclitus* not only will eat larvæ, pupæ, and the shells of the same, but that it will eat these over and over again, when hard pressed by hunger.

In order to test the activity of *Fundulus heteroclitus* as an enemy of the water tiger, larva of *Dytiscus*, I performed numerous experiments at Woods Hole, Mass., using medium-sized killifish and rather large water tigers. In the presence of mosquito larvæ the water tigers were not eaten, but after the mosquito larvæ had been captured the water tigers were soon devoured.

As Dr. G. H. Parker (7, 8) has shown the importance of the visual sense as well as the olfactory sense in the teleosts, particularly *Fundulus heteroclitus*, experiments on the attractiveness of larval shells to *Fundulus* were hardly necessary. It seemed wise, however, to make a few such experiments.

Four medium-sized male *Funduli* were placed in a jar containing larval shells and a few mosquito larvæ. The larvæ were seized instantly, but not all of them had been captured before the voracious killifishes seized and partly devoured larval and pupal shells. The larval shells were spit out rather forcibly on being about half swallowed. The spitting reaction was not limited to larval and pupal shells, however. In many of my experiments with killifish placed in jars with large numbers of mosquito larvæ, a sated individual would act like the small boy at Thanksgiving, and seize larvæ which it could not stomach. After a few such "tries" the fish sometimes rest and meditate on the bottom of the aquarium, occasionally seizing a few other larvæ and swallowing them. From our experiments there is little evidence of a selection of one particular species of mosquito larva. The selection of the mosquito larva in preference to water tigers, *Notonecta*, shrimps, spiders, daphnids and vegetable food, is attributable, I believe, to the stimulus of the extremely active mosquito larva to the visual sense of the fish. The fish always selected motile larvæ in preference to dead or quiescent ones; they chose the larvæ as they came to the surface to breathe or seized them as they were sinking. While it is true that the fish also ate dead larvæ and those which were quietly resting at the bottom of the jar, they also seized other animals, bits of alga, in fact almost anything which appealed to the eye. The olfactory and gustatory senses came into play in the rejection of unsuitable or distasteful food.

Smell, I maintain, is a secondary sense in the capture of mosquito larvæ by the killifish, *Fundulus heteroclitus*.

CONCLUSIONS

The greatest natural enemy of the salt-marsh mosquito is the barred killifish, *Fundulus heteroclitus*. It also eats many green-head flies.

Fundulus heteroclitus captures larvæ, pupæ and adults of the mosquito, eating as many as 50 a day and killing many more.

The vast hordes of fishes which migrate to the shallows and even into almost fresh water render the species especially formidable.

The number of enemies of the mosquito which are eaten by *Fundulus heteroclitus* is negligible and is more than compensated for by the great preponderance of mosquitoes in the diet of the fish.

The ease with which *Fundulus* may be artificially fertilized and the remarkable vigor and resistance of the young embryos make the stocking of pools and streams with this species a simple matter.

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